US009331789B2

(12) **United States Patent**
Sato

(10) **Patent No.: US 9,331,789 B2**
(45) **Date of Patent: May 3, 2016**

(54) **TRANSMITTER OPTICAL MODULE IMPLEMENTED WITH THERMO-ELECTRIC CONTROLLER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 210 days.

(21) Appl. No.: **14/075,876**

(22) Filed: **Nov. 8, 2013**

(65) **Prior Publication Data**

US 2014/0126918 A1 May 8, 2014

(30) **Foreign Application Priority Data**

Nov. 8, 2012 (JP) 2012-245959

(51) **Int. Cl.**

H04B 10/06	(2006.01)
H04B 10/50	(2013.01)
G02B 6/42	(2006.01)

(52) **U.S. Cl.**
CPC ***H04B 10/50*** (2013.01); ***G02B 6/4271*** (2013.01); *G02B 6/4215* (2013.01); *G02B 6/4292* (2013.01)

(58) **Field of Classification Search**
CPC G02B 6/00; G02B 6/36; G02B 6/42; G02F 1/09; H04B 10/50; H04J 14/02
USPC 398/182, 91, 79; 385/93, 92, 88, 24; 257/696, 458, 225; 250/214.1
See application file for complete search history.

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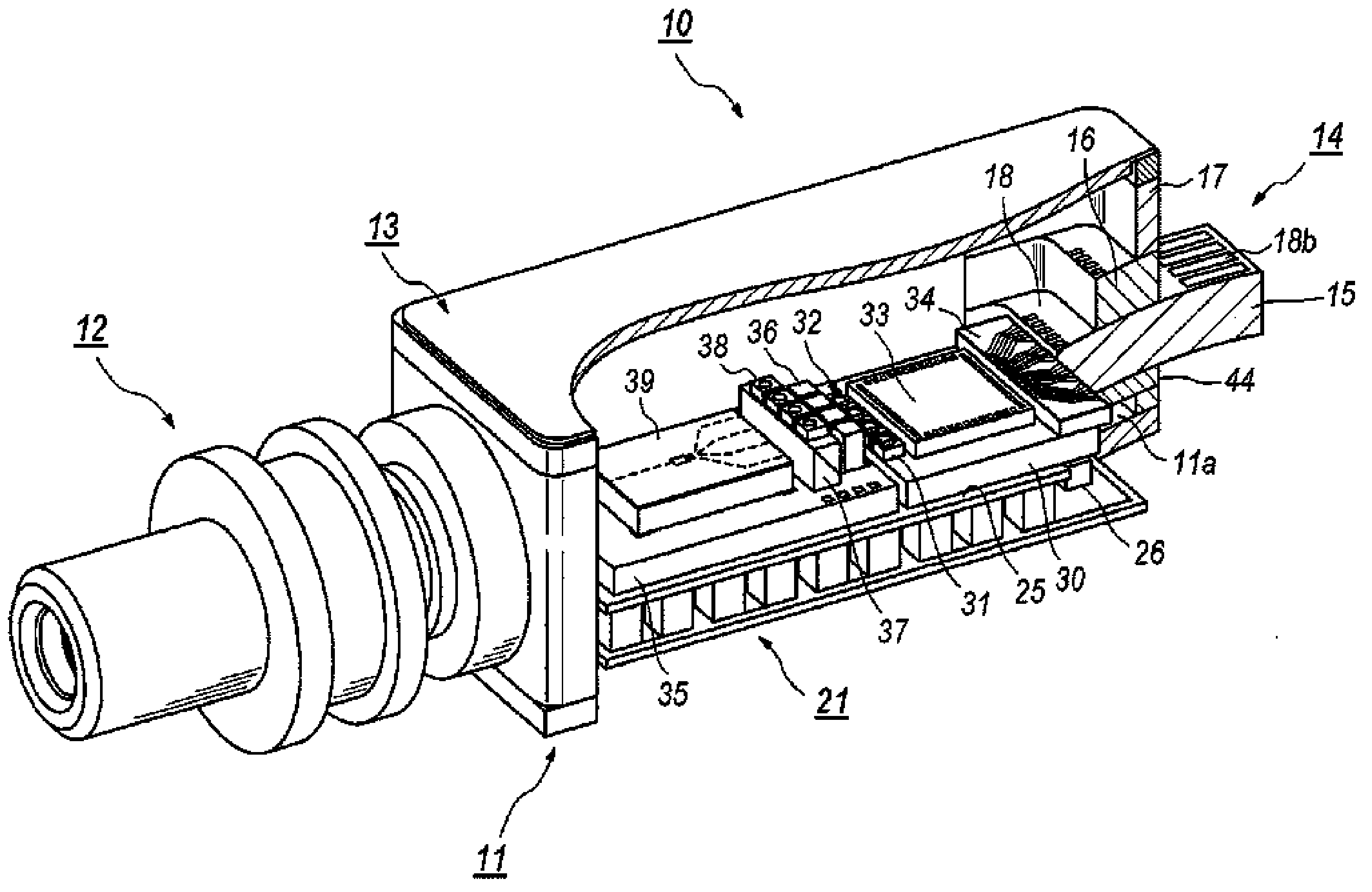
(57) **ABSTRACT**

A transmitter optical module is disclosed. The optical module includes a plurality of LDs each emitting light with specific wavelengths different from others, a TEC including a post in bottom plate thereof through which currents to driver the TEC is supplied, and a body portion including an electrical plug made of multi-layered ceramics. The multi-layered ceramic in a lowermost ceramic layer thereof provides electrical pads to supply current to the TEC through the post. The post and the pads are configured in side-by-side arrangement such that the post in the TEC is put between two pads in the lowermost ceramic layer.

13 Claims, 9 Drawing Sheets



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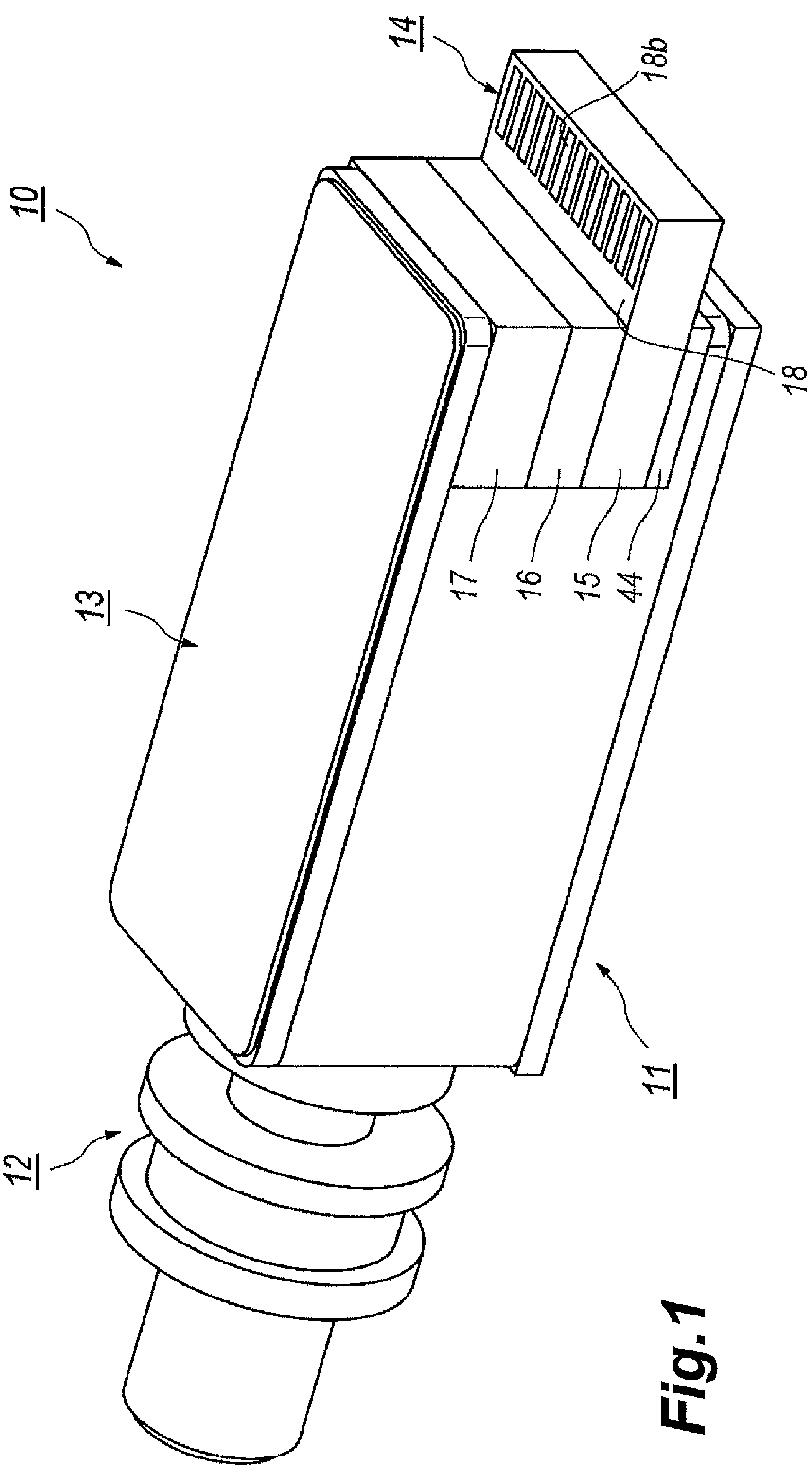

Fig.1

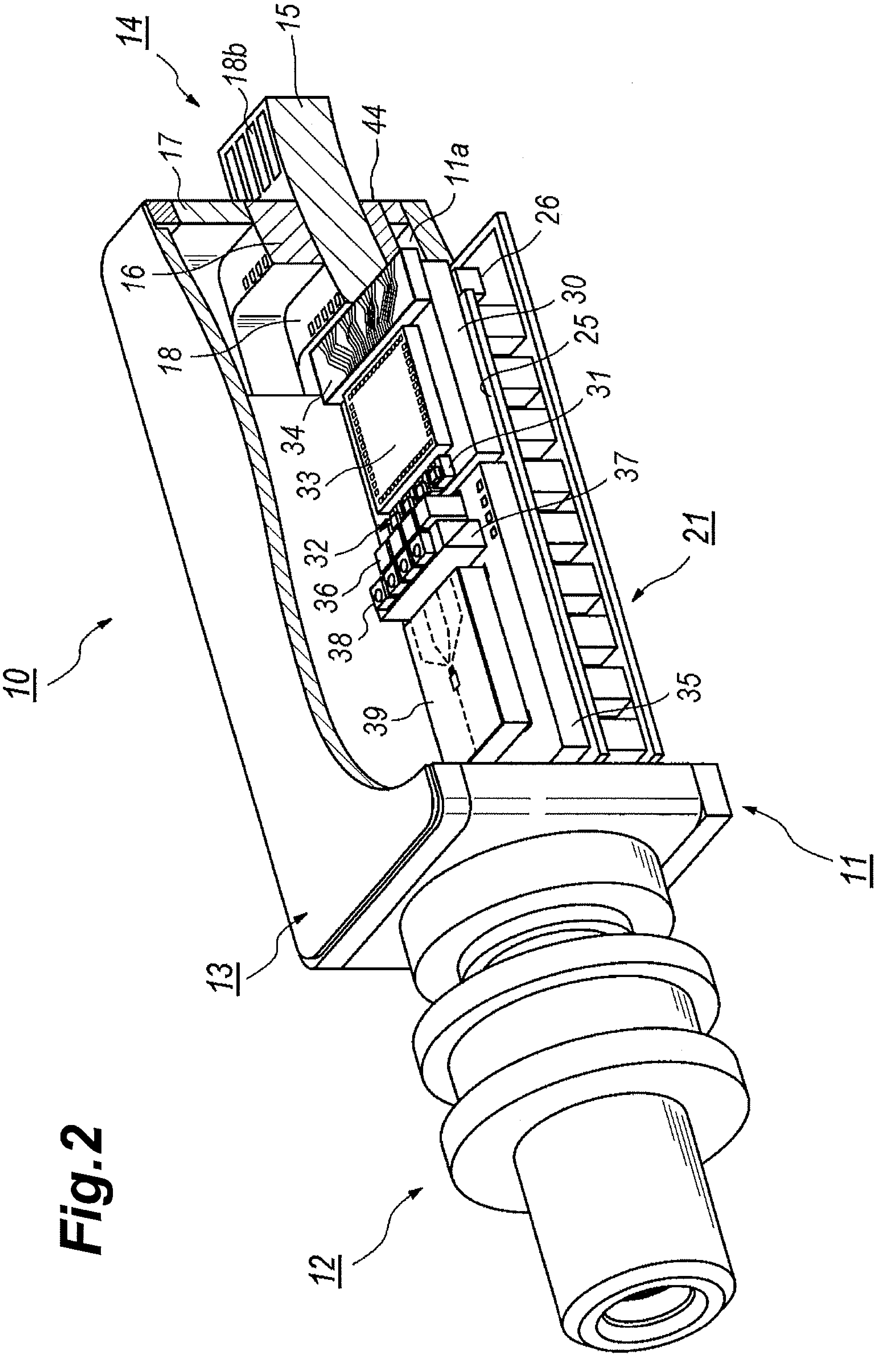
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Fig.2

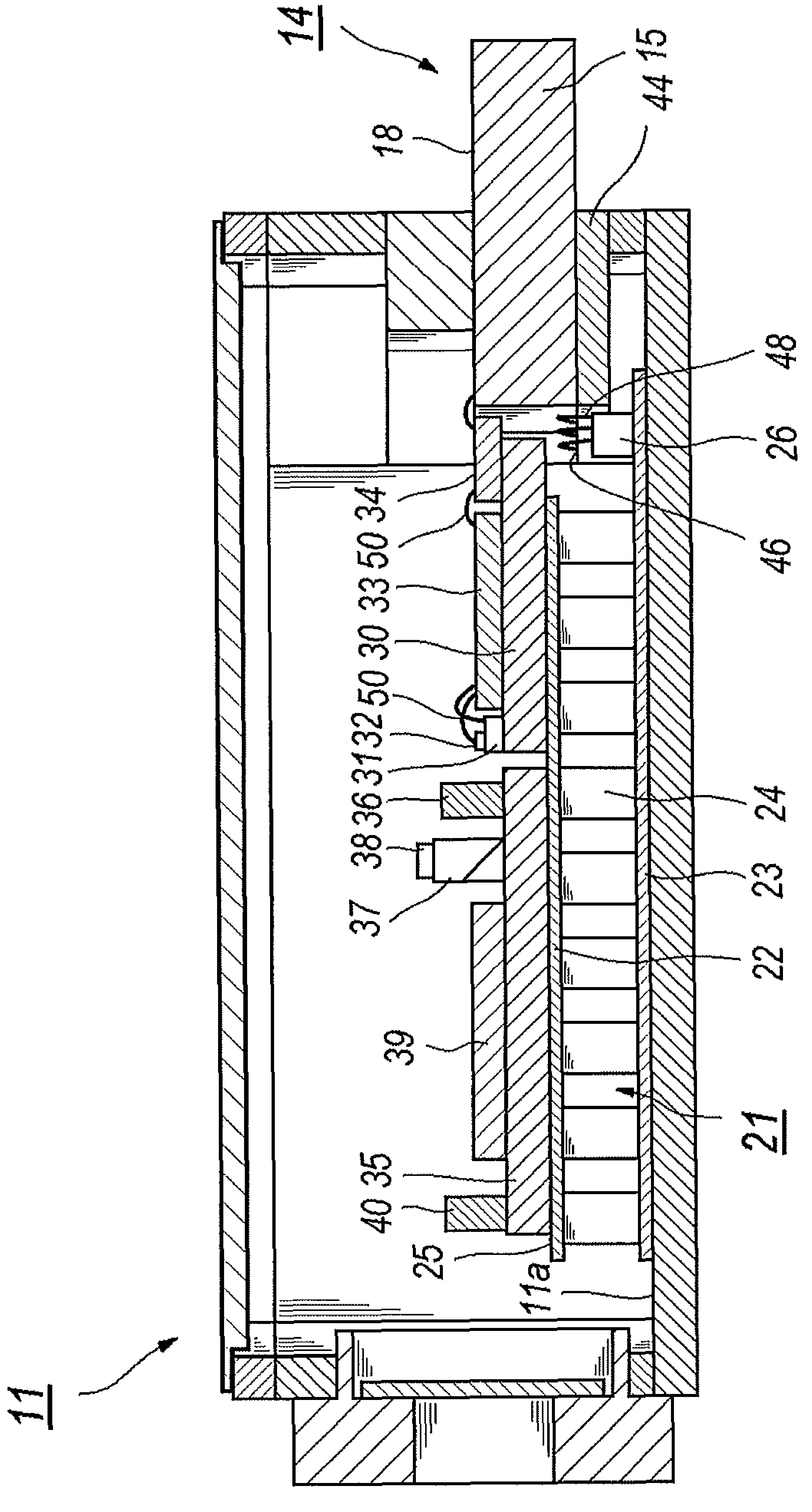
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Fig.3

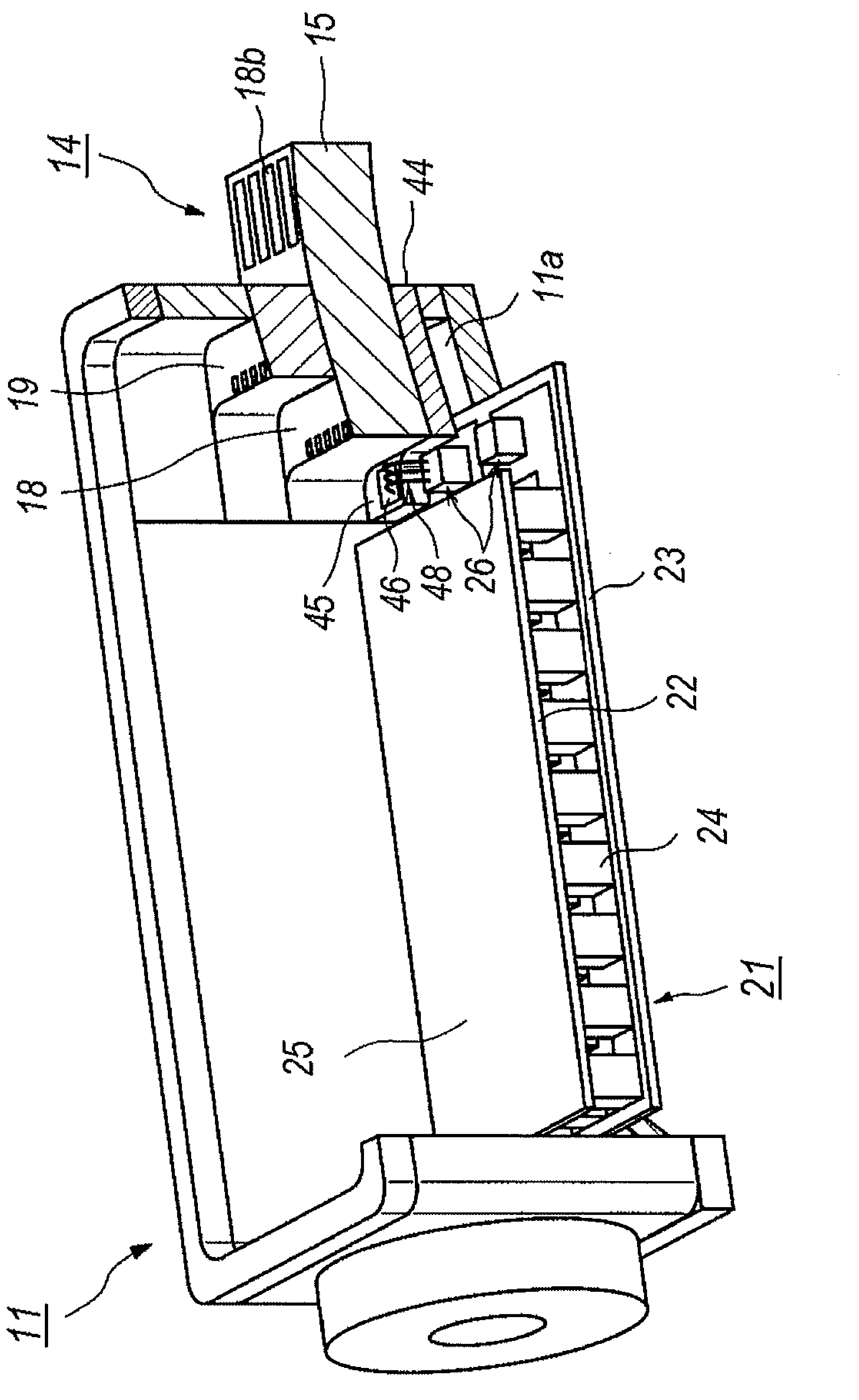


Fig.4

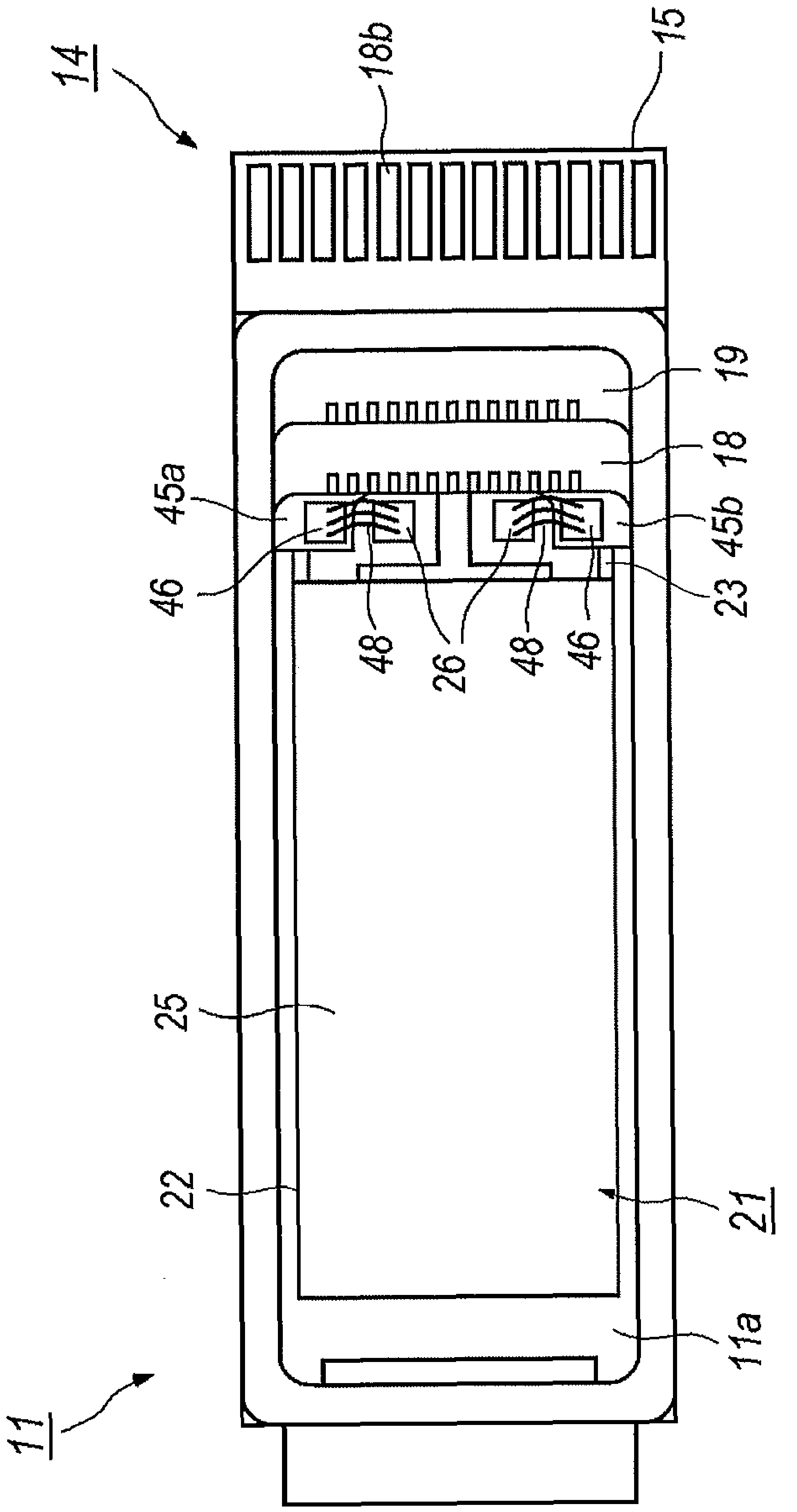


Fig.5

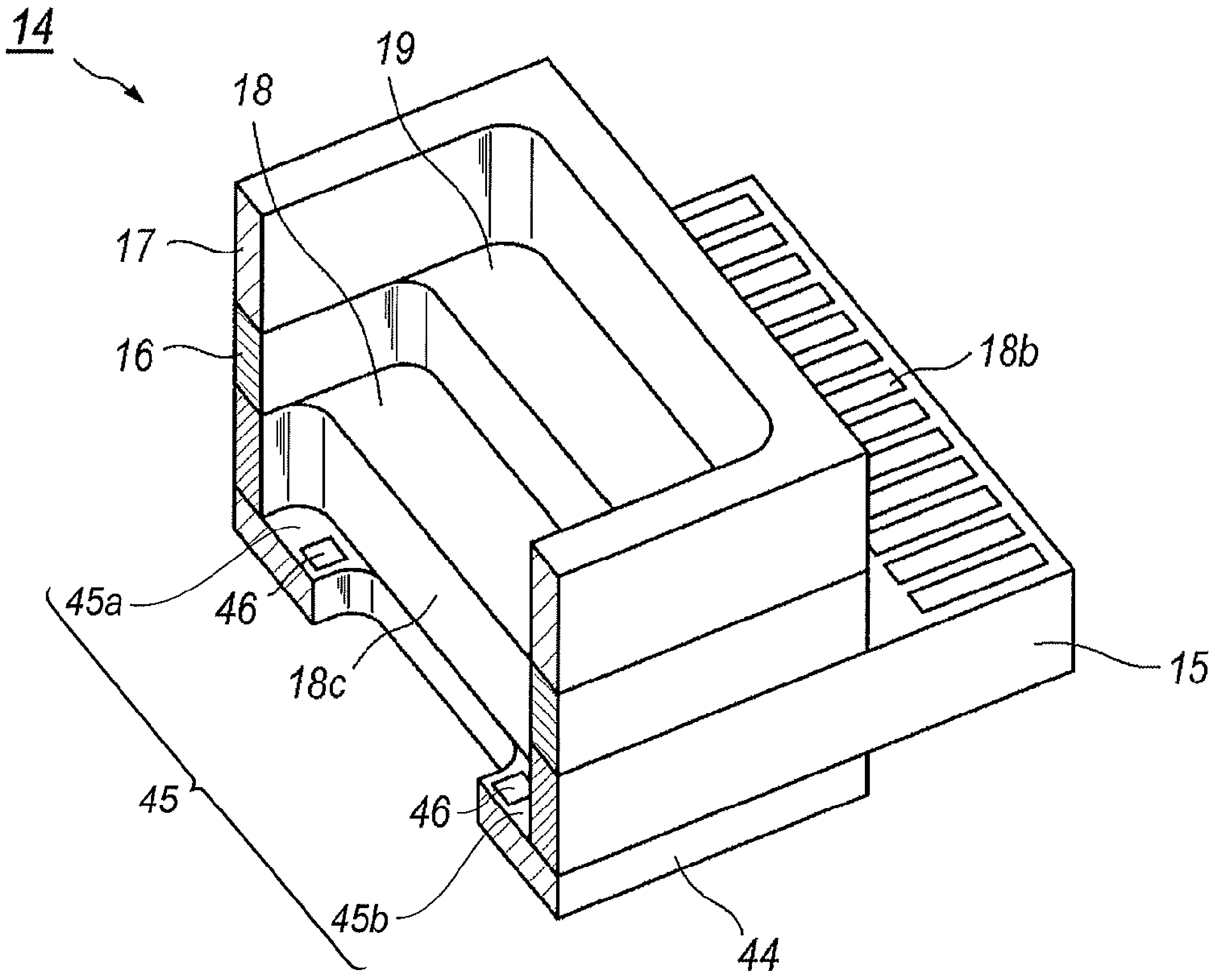


Fig.6

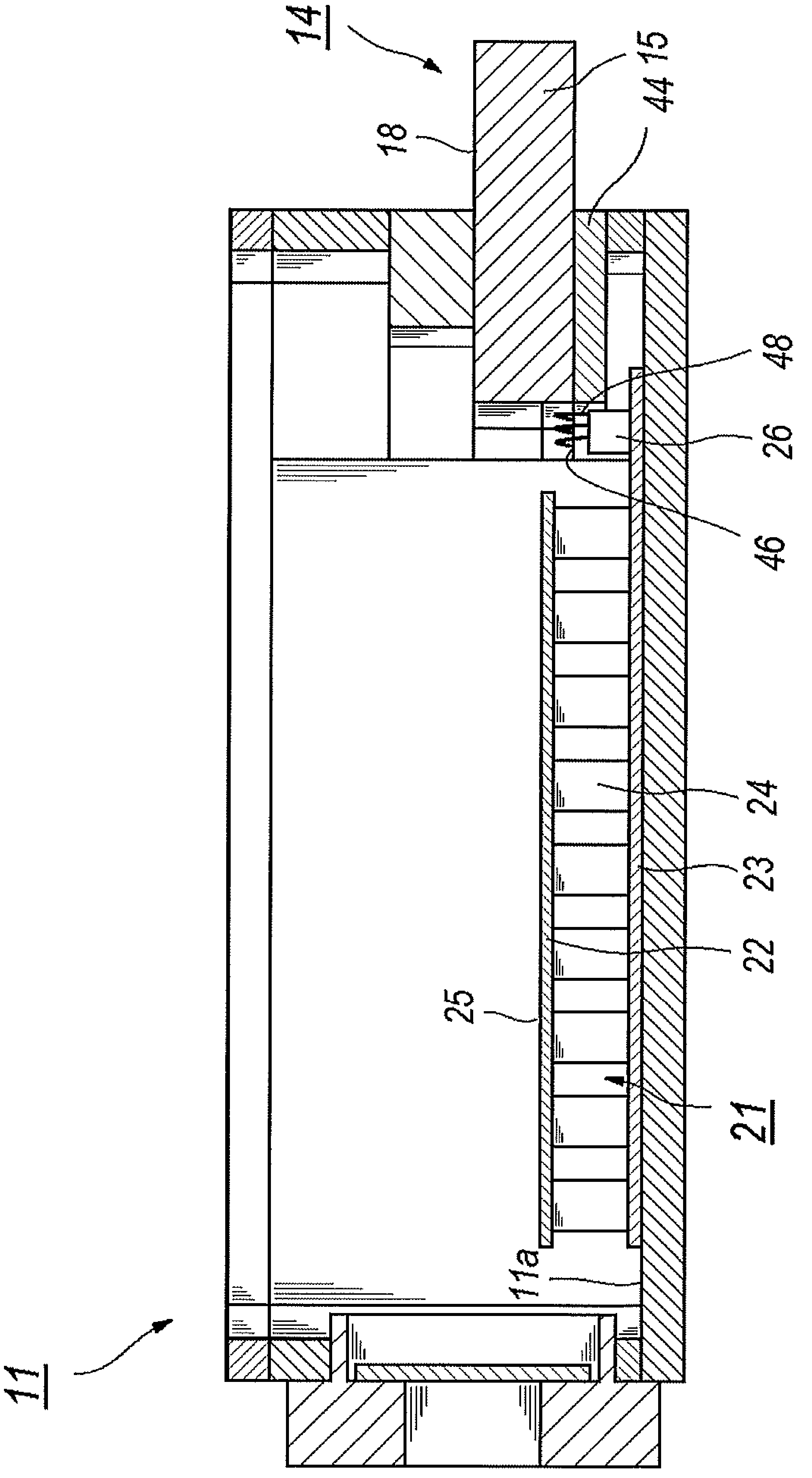


Fig.7

Fig.8

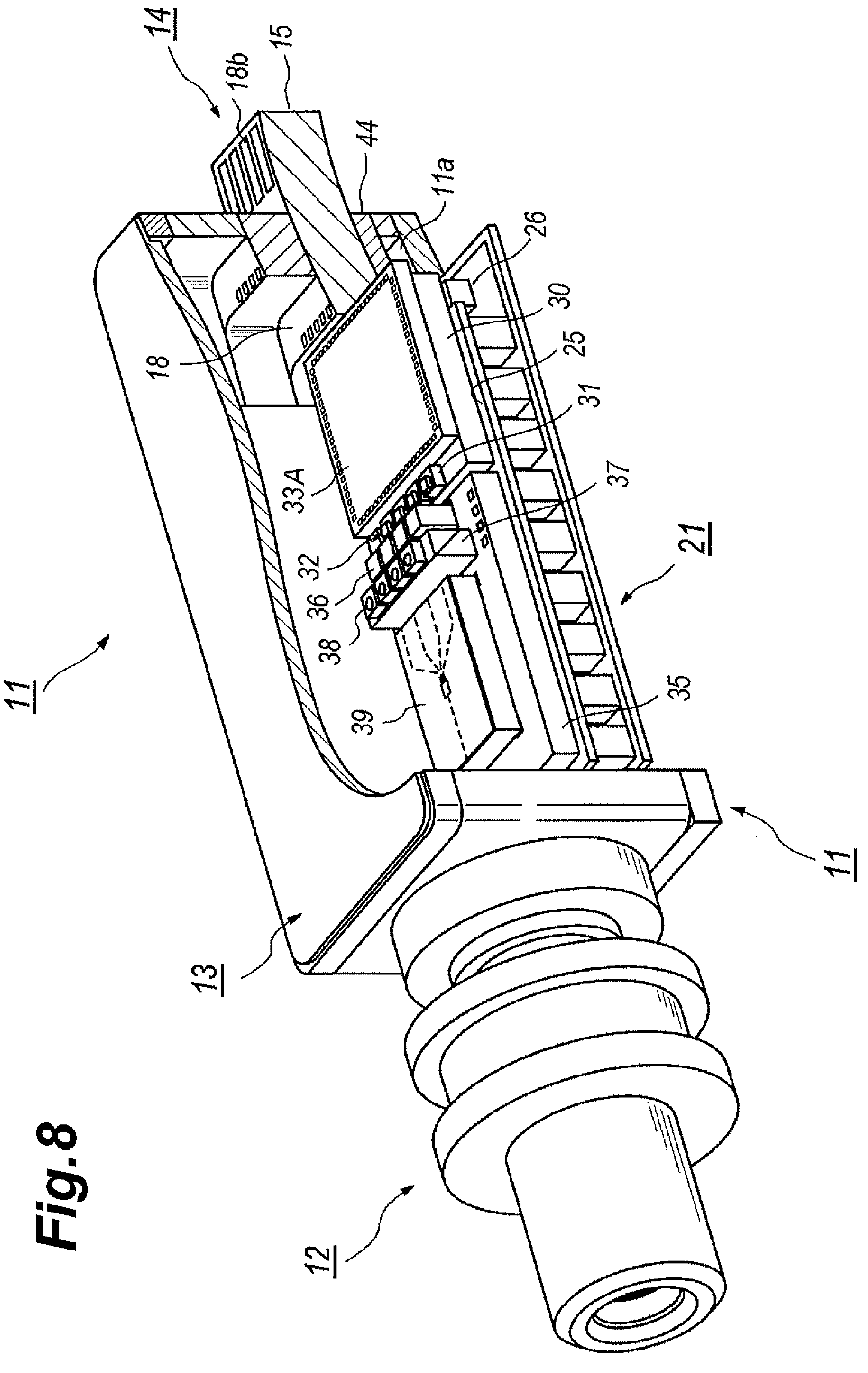
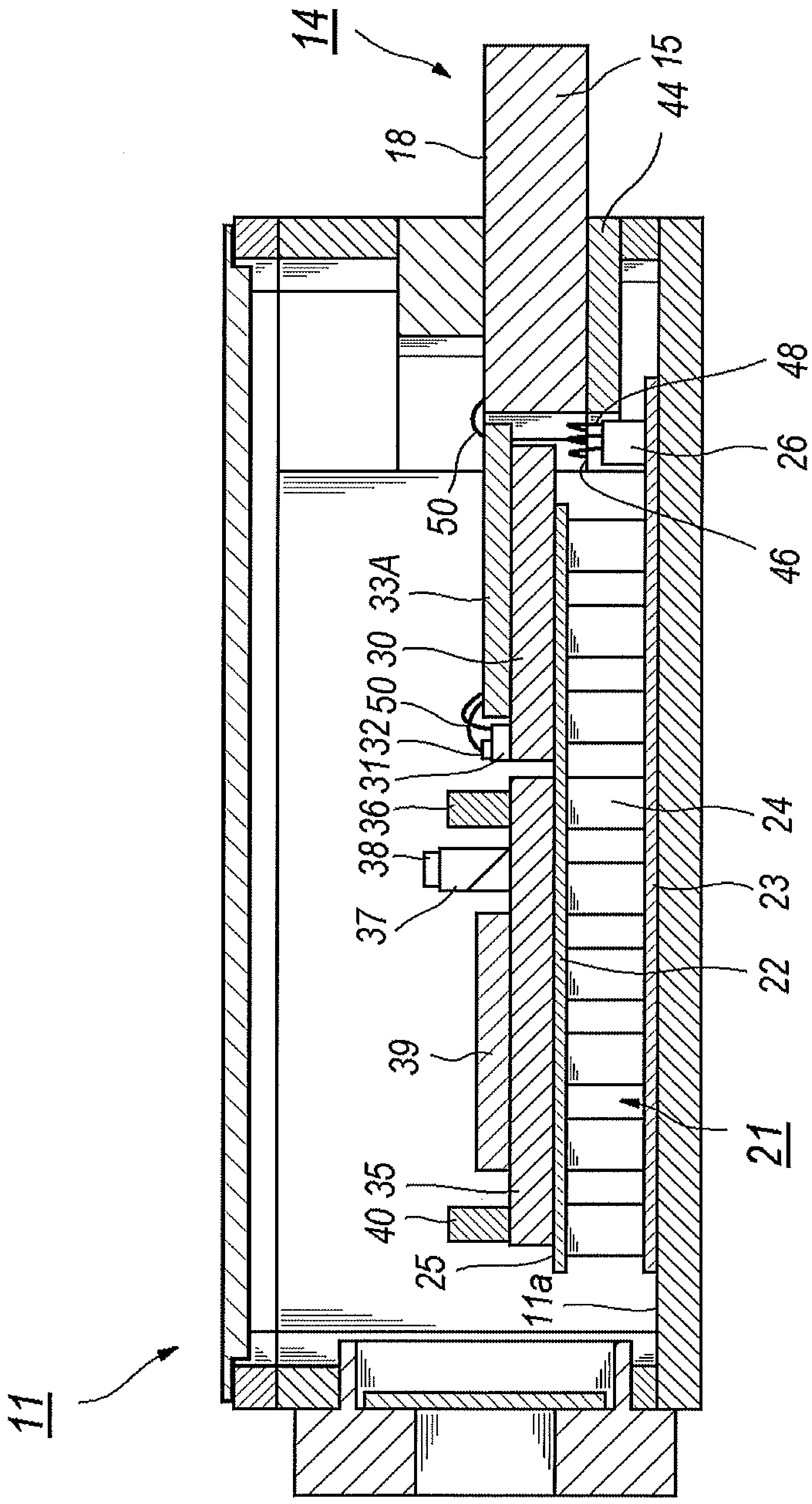


Fig.9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TRANSMITTER OPTICAL MODULE IMPLEMENTED WITH THERMO-ELECTRIC CONTROLLER

BACKGROUND

1. Field

The present application relates to a transmitter optical module that installs a thermo-electric controller (hereafter denoted as TEC) therein.

2. Description of the Related Art

A transmitter optical module has been used as an optical signal source for the optical communication system, and/or a pumping source for an optical fiber amplifier. The transmitter optical module installs therein a semiconductor laser diode (hereafter denoted as LD) to convert an electrical signal into an optical signal. Because an emission wavelength of the LD strongly depends on an operating temperature of the LD, the transmitter optical module is often implemented with a TEC to keep a temperature of an LD constant. The U.S. Pat. No. 6,821,030, U.S. Pat. No. 7,106,978, and U.S. Pat. No. 8,213,472, have been disclosed such an transmitter optical module installing a TEC therein.

The present application is to provide an improved arrangement to supply current to a TEC installed within the transmitter optical module.

SUMMARY

A transmitter optical module according to one of embodiments comprises a plurality of LDs, a TEC, and a body portion enclosing the LDs and the TEC therein. The TEC includes a bottom plate on which posts to supply current to the TEC is provided. The body portion includes an electrical plug made of multi-layered ceramics. The multi-layered ceramics provides pads through which the current to drive the TEC is supplied. A feature of the transmitter optical module is that the pads in the multi-layered ceramics and the posts in the bottom plate of the TEC are arranged in side-by-side such that the pads put the posts therebetween; and are connected to the posts via bonding wires.

One of embodiments includes a lowermost ceramic layer and a first ceramic layer provided on the lowermost ceramic layer. The pads are formed on the top surface of the lowermost ceramic layer. The first ceramic layer provides interconnections on the top surface and the back surface thereof. The pads on the lowermost ceramic layer are electrically connected to the interconnections formed in the back surface of the first ceramic layer and brought to the outside of the body portion. The bottom plate of the TEC is slipped under the lowermost ceramic layer; while, the first ceramic layer exposes top surface of the lowermost ceramic layer only in both sides thereof. Thus, the pads formed in the exposed top surface of the lowermost ceramic layer puts the posts in the bottom plate of the TEC therebetween.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting and non-exhaustive embodiments will be described with reference to the following figures:

FIG. **1** shows an outer appearance of a transmitter optical module according to an embodiment;

FIG. **2** shows an inside of the transmitter optical module illustrated in FIG. **1**;

FIG. **3** shows a side cross section of the transmitter optical module illustrated in FIGS. **1** and **2**;

FIG. **4** illustrates a TEC with a post and a lowermost ceramic layer with a pad disposed in side-by-side arrangement to the post;

FIG. **5** is a plan view showing the post, the pad and bonding wires electrically connecting the pad to the post;

FIG. **6** magnifies a rear portion of the multi-layered ceramics providing the pad in the top surface of the lowermost layer thereof;

FIG. **7** shows a side cross section of the TEC with the post, the multi-layered ceramics with the pad on a top surface of the lowermost layer;

FIG. **8** shows an inside of a transmitter optical module according to another embodiment; and

FIG. **9** shows a side cross section of the TEC, electrical elements on the TEC, and the multi-layered ceramics implemented within the transmitter optical module shown in FIG. **8**.

DETAILED DESCRIPTION

Some embodiments will be described as referring to drawings. A transmitter optical module shown in FIGS. **1** to **3** includes a plurality of LDs within a package, and each of LDs emits light with a specific wavelength different from others. Such a transmitter optical module is installed in an optical transceiver applicable to the wavelength division multiplexing (WDM) system.

FIG. **1** shows an outer appearance of the transmitter optical module **10** according to an embodiment. The transmitter optical module **10** shown in the figures primarily comprises a body portion **11** and a coupling portion **12**. The body portion **11** has a box shape with a ceiling **13** to seal an inside thereof hermetically. A rear end of the body portion **11** provides an electrical plug to communicate with an external circuit electrically. The coupling portion **12** is assembled with one wall of the body portion **11** in a side opposite to the electrical plug **14**. The description below assumes only for the explanation sake that the front side of the module **10** corresponds to a side where the coupling portion **12** is provided; while, the rear is a side the electrical plug **14** is formed.

FIG. **2** is also a perspective drawing of the optical module viewed from the front top, where a part of the body portion **11** is removed to show the inside thereof. FIG. **3** is a cross section along the longitudinal direction of the body portion **11** of the optical module **10**. The body portion **11** installs a TEC **21**, the LDs **32**, a driver **33**, and some optical components therein. The LDs **32** and the driver **33** are mounted on the TEC **21** through the first carrier **30**; while, the optical components such as first lenses **36**, monitor photodiodes (hereafter denoted as PD) **38**, an optical multiplexer **39**, and the second lens **40** are mounted on the TEC **21** through the second carrier **35**. Further specifically, the LDs **32** are mounted on the first carrier via LD sub-mounts **31**; while, the monitor PDs **38** are mounted on the second carrier **35** via a beam splitter **37**. The first carrier **30** also mounts a wiring substrate **34** thereon. Two carriers, **30** and **35**, are preferably made of material having good thermal conductivity, such as aluminum nitride (AlN), copper tungsten (CuW), and so on.

Each of LDs **32** emits light with a specific wavelength different from others. The optical multiplexer **39** multiplexes light depending on the wavelengths thereof to generate a single beam to be coupled with a single fiber through the second lens **40**. The embodiment shown in the figures installs four (4) LDs; and the wavelengths of light emitted from the LDs **32** follow the LAN-WDM standard where a wavelength difference to the next grid is defined to be around 5 nm. The body portion **11**, as already explained, has a box shape with 5 to 8 mm square. The coupling portion **12**, which receives an external ferrule secured in a tip of an external fiber, couples the LDs in the body portion **11** optically with the external fiber. The electrical plug **14**, which extends outwardly, is made of multi-layered ceramics; where the embodiment shown in the figures has four ceramic layers, **15** to **17**, and **44**.

The first ceramic layer **15** in the electrical plug **14** includes a top surface **18**, on which electrical pads **18***b* are formed, and a back surface **20** where other electrical pads may be formed but not explicitly illustrated in the figures. The electrical plug **14** is electrically connected to external circuits with, for instance, a flexible printed circuit (FPC) board, and/or electrical connectors with lead terminals in contact with the pad **18***b*.

The driver **33** mounted on the first carrier **30** is electrically connected to the wiring substrate **34** and the LDs **32** with bonding wires **50**. The wiring substrate **34** provides interconnection with an arrangement of the micro-strip line and/or the coplanar line to secure the transmission impedance thereof. Because the driver **33**, or the LDs **32**, operates in a speed reaching, or occasionally exceeding, 10 Gbps; the impedance matching of the transmission lines to that of the driver **33** and the LDs **32** are one of key factors to maintain the signal quality. The interconnections on the wiring substrate **34** suppress the degradation of the signal quality due to not only the impedance mismatching but elongated bonding wires.

The transmitter optical module **10** of the embodiment further provides an arrangement to suppress the degradation of the signal; that is, the top level of the wiring substrate **34**, that of the first ceramic layer **18** where the interconnections from the pads **18***b* are formed, and that of the driver **33** are substantially leveled; which further shortens a length of the bonding wire.

In a transmitter optical module applied to the wavelength division multiplexing (WDM) system, the precise control of an operating temperature of an LD is inevitable because an LD inherently shows large temperature dependence of performances thereof. For instance, the emission wavelength, the emission efficiency, and so on strongly depend on an operating temperature. The transmitter optical module **10** of the present embodiment installs a TEC with a large size to control a temperature of not only the LDs **32** but the driver **33**, and the optical multiplexer **39**. The TEC **21** is mounted on the bottom **11***a* of the body portion **11**.

The first and second carriers, **30** and **35**, of the embodiment are disposed on the top plate **22** of the TEC **21** in front and rear of the body portion **11**. Although the LDs **32** is mounted on respective LD sub-mounts **31** in the present embodiment, the LD sub-mounts **31** may be integrally formed in a single body. The first carrier **30**, or the LD sub-mount **31**, mounts a temperature sensor to detect the temperature of the LDs **32**, or that of the driver **33** to set the temperature of the devices, **32** or **33**, in a preset condition.

The driver **33** integrates a plurality of LD drivers each driving respective LDs **32** independently. The driver **33** may also integrate an automatic power control (APC) circuit to keep an average output power of the LD **32** in constant by feeding the output of the monitor PD **33** back to the APC circuit. The driver **33** may integrate four (4) APC circuits each operating for respective LDs **32**. The LDs **32** receive driving signals from the driver **33** via bonding wires **50**.

The second carrier **35** mounts optical components, namely, the first lenses **36**, the monitor PDs **38**, the optical multiplexer **39** and the second lens **40**. The first lenses **36** are placed in front of the respective LDs **32** in an arrayed arrangement to concentrate light beams emitted from the respective LDs **32**. The concentrated beams enter the beam splitter **37** on which the monitor PDs **38** are mounted. The beam splitter **37** transmits a portion of the concentrated beams, the primary portion thereof, toward the optical multiplexer **39**; while, reflects a rest portion of the concentrated beams toward the monitor PDs **38**. The rest portion of the beam is 1 to 10% of the concentrated beam. The monitor PDs **38**, which are mounted on the beam splitter **37**, receive thus divided rest portion of the concentrated beams, and generate photocurrents. The photocurrents are fed back to the APC circuits so as to maintain the output power of respective LDs **32** in constant.

Next, the arrangements around the TEC **21** will be described in detail. The TEC **21** includes a top plate **22**, a bottom plate **23**, and a plurality of Peltier elements **24** provided between two plates, **22** and **23**. The bottom plate **23** faces and comes in physical contact with the bottom **11***a* of the body portion **11**, while, the top surface **25** of the top plate **22** mounts optical and electrical components thereon through carriers, **30** and **35**. The top plate **22** extends rearward to just in front of the first ceramic layer **15** in the electrical plug **14**. Moreover, the level of the top surface **25** is set between the top surface **18** of first ceramic layer **15** and the top surface **45** of the fourth ceramic layer **44**.

The bottom plate **23** of the TEC **22** slips under the first and fourth ceramic layers, **15** and **44**, in the rear end thereof. A portion of the bottom plate **23** not covered by the top plate **22** provides posts **26** arranged in side by side with respect to the longitudinal direction of the body portion **11**. The posts **26** have a rectangular cross section in the present embodiment, but, a pillared shape with a circular cross section is applicable. The posts **26** in a top thereof are electrically connected to the pads in the top surface **45** of the fourth ceramic layer **44**.

FIG. **4** is a perspective view of the TEC **21** set within the body portion **11**; FIG. **5** is a plan view; and FIG. **6** magnifies a rear end of the body portion **11** to show an arrangement around the TEC **21**. Referring to FIG. **6**, the electrical plug **14** includes first to fourth ceramic layers, **15** to **17** and **44**, where the fourth ceramic layer **44** is the lowermost layer, while, the third ceramic layer **17** is the topmost layer in the present embodiment. Although the embodiment provides four ceramic layers, the body portion **11** may be formed by five or more ceramic layers.

The first ceramic layer **15** extends externally and internally to form a terrace where the external pads **18***b*, internal pads, and interconnections electrically connecting them are provided. The latter two elements, namely, the internal pads and the interconnections are not explicitly illustrated in the figure. The inner edge **18***c* of the top surface **18** in respective sides thereof is back off to expose the top surface **45** of the fourth ceramic layer **44** to form exposed areas **45***a* and **45***b* of the lowermost layers **44**.

The second ceramic layer **16**, which is put on the first ceramic layer **15**, provides a top surface **19** exposed inside of the body portion **11**. The top surface **19** in a front edge thereof is back off to expose the top surface **18** of the first ceramic layer **15**. The top surface **19** of the second ceramic layer also forms interconnection electrically connected to the driver **33**. Because the top surface **19** is not extended outside of the body portion **11**, via holes piercing the second ceramic layer **16** electrically connect the interconnections on the top surface **19** to those formed on the top surface **18** of the first ceramic layer **15**. Thus, the interconnections provided on the top surface **19** are preferably provided for signals containing lower frequencies.

The third ceramic layer **17**, which is put on the second ceramic layer **16**, is configured to be a wall to form a cavity within the body portion **11**. The third ceramic layer **17** exposes the top surface **19** of the second ceramic layer **16**.

While, the fourth ceramic layer **44** is provided under the first ceramic layer **15** and provides the top surface **45** exposed within the inside of the body portion **11** and respective sides thereof.

The top surface **45** provides an electrical pads **46** on the exposed areas **45***a* and **45***b*. Because the top surface **45** of the fourth ceramic layer **44** is exposed only in respective sides of the body portion **11** to form the exposed areas **45***a* and **45***b* of the top surface **45**, the bottom plate **23** of the TEC **21** may be extended between the exposed areas **45***a* and **45***b* of the top surface **45**. That is, the rear end of the bottom plate **23** is set in a cut between the exposed areas **45***a* and **45***b* of the top surface **45**. Moreover, the rear portion of the bottom plate **23** provides the posts **26** to supply a current to the TEC **21**. Accordingly, the posts **26** on the bottom plate **23** and the electrical pads **46** on the top surface **45** are arranged in side-by-side. Connecting the electrical pad **46** to the post **26** with bonding wires **48**, the current to drive the TEC **21** is supplied. This arrangement of two electrodes, **26** and **46**, are suitable for drawing a plurality of bonding wires **48** with a shorter length. Moreover, the side-by-side arrangement of the electrodes may be formed only by stacking the ceramic layers, **44** and **15**, without cutting, processing, and so on of the ceramic material.

The electrical pad **46** is connected to the pad **18***b* prepared in the plug **14** by a via hole piercing the first ceramic layer **15**. When the electrical pad **46** is connected to another pad formed in the back surface of the first ceramic layer **15**, which is not illustrated in the figures, the electrical pad **46** is directly connected to those pads without passing any via holes. As shown in the figures, the bonding wires **48** connecting two pads **46** with the posts **26**, extend laterally of the body portion **11** and with a relatively shorter length.

FIG. **7** shows a side cross section of the TEC **21** showing a positional relation of the TEC **21**, the first and fourth ceramic layers, **15** and **44**, and the bonding wires **48**. As shown in FIG. **7**, the bonding wires **48** in a top level thereof is lowered from the top surface **25** of the TEC **21**. Accordingly, the top surface **45** of the fourth ceramic layer **44** and the top of the post **26** are set in a level lowered from the top surface **25** of the TEC **21**. Accordingly, even when the first carrier **30** extrudes from the edge of the top plate **22** of the TEC **21** rearward, the first carrier **30** does not interfere with the bonding wires **48**.

As shown in FIG. **3**, the wiring substrate **34** also protrudes rearward from the edge of the first carrier **30** so as to set the rear edge of the wiring substrate **34** further close to the front edge of the first ceramic layer **15**. This arrangement enables to connect the interconnection on the top surface **18** of the first ceramic layer **15** with the interconnection on the wiring substrate with a shorter bonding wire. Because the position of the LDs **32** measured from the front wall of the body portion is optically determined, and the driver **33** has definite planar dimensions, the rear edge of the driver **33** is sometimes apart from the front edge of the first ceramic layer **15**, which probably results in a lengthened bonding wires between the driver **33** and the first ceramic layer **15**. The wiring substrate **34** with an optional length may compensate such a lengthened bonding wire. Shortened bonding wire may suppress degradation of the signal quality in high frequencies.

In another situation, when a pitch between the electrodes on the top surface **18** of the first ceramic layer **15** is far different form a pitch between the pads formed on the driver **33**, the wiring substrate **34** is provided for a device to convert the pitches. The driver **33** is an integrated circuit (IC) on a silicon wafer, and has a minimum die area to build the necessary circuit therein. Accordingly, the pitch between the pads on the driver **33** is designed to be 100 to 200 μm at most. On the other hand, the electrodes provided in the electrical plug **14** often have the pitch of at least 200 to 400 μm. Moreover, when an optical module has plural channels operating over 10 Gbps and the pads within the driver **33** has the pitch different from the pitch of the electrodes; a time lag becomes large between signals carried on the outermost interconnection and those on the inner interconnection. The wiring substrate **34** adequately compensates the time lag by drawing interconnection on the substrate **34** such that the inner interconnection has a length substantially equal to a length of the outer interconnection.

The arrangement of the TEC **21**, the post **26**, and the electrical pad **46** of the fourth ceramic layer **44** make the electrical plug **14** to be formed only in the rear end of the body portion **11**. Thus, the transmitter optical module with a slimed width may be easily available. Such a module, even when the module installs a plurality of optical sources to realize a total transmission speed of 40 Gbps and/or 100 Gbps, may be installed within a newly proposed transceivers type of CFP**2**, CFP**4**, and so on having an optical connector of the LC type.

FIGS. **8** and **9** show another embodiment, where the transmitter optical module shown in FIGS. **8** and **9** removes the wiring substrate **34** provided on the first carrier **30** and electrically connecting the interconnection on the first ceramic layer **15** to the driver **33**A. When the pads formed within the driver **33**A have a relatively wider pitch substantially equal to the pitch of the electrodes **18***b* on the first ceramic layer **18**, because the driver **33** integrates supplemental circuit therein and resultantly the die area inevitably becomes large, the transmitter module **10** may remove the wiring substrate **34**. The embodiment shown in FIG. **9** sets the rear end of driver **33**A close to the front edge of the first ceramic layer **15**. The arrangement shown in FIGS. **8** and **9** removes the bonding wire **50** connecting the interconnection provided on the wiring substrate **34** and the driver **33**A, which suppresses the degradation due to the existence of this bonding wire.

In the foregoing detailed description, the transmitter optical module of the present invention have been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the present invention. The present specification and figures are accordingly to be regarded as illustrative rather than restrictive.

What is claimed is:

1. A transmitter optical module, comprising:

a semiconductor laser diode (LD) to emit light with a specific wavelength;

a thermo-electric-controller (TEC) to control a temperature of the (LD), the TEC including a bottom plate and a post provided on the bottom plate; and

a body portion configured to enclose the LD and the TEC therein hermetically, the body portion including an electrical plug made of multi-layered ceramics including a lowermost layer providing an electrical pad on a top surface thereof exposed within the body portion, the electrical pad supplying a current to the TEC through the post,

wherein the post and the electrical pad are configured in side-by-side arrangement and electrically connected with a bonding wire,

wherein the multi-layered ceramics of the electrical plug further includes a first ceramic layer providing an interconnection electrically connecting an inside of the body portion to an outside thereof, the interconnection of the first layer providing an electrical pad in an end outside of the body portion.

2. The transmitter optical module of claim **1**,

wherein the bottom plate of the TEC is slipped under the lowermost layer of the multi-layered ceramics of the electrical plug.

3. The transmitter optical module of claim **1**,

wherein the post on the bottom plate of the TEC has a level lower than a level of the top surface of the lowermost layer exposed within the body portion.

4. The transmitter optical module of claim **1**,

wherein the first ceramic layer provides interconnections in a top surface and a back surface thereof, the electric pad on the top surface of the lowermost ceramic layer exposed within the body portion being electrically connected to the interconnection in the back surface of the first ceramic layer.

5. The transmitter optical module of claim **1**,

wherein the bonding wire has a top level lower than a top level of the TEC.

6. A transmitter optical module, comprising:

a plurality of laser diodes (LDs) each emitting light having wavelengths different from each other;

a thermo-electric-controller (TEC) to control a temperature of the LDs, the TEC including a bottom plate and a post provided on the bottom plate;

a body portion configured to enclose the LDs and the TEC therein hermetically, the body portion including an electrical plug made of multi-layered ceramics including an electrical pad that supplies a current to the TEC through the post, the electrical pad being arranged side-by-side with respect to the post of the TEC;

a driver for driving the LDs electrically; and

an optical multiplexer that multiplexes the light emitted from the LDs,

wherein the LDs and the driver are installed on the IBC through a first carrier, and the optical multiplexer is installed on the TEC through a second carrier different from the first carrier.

7. The transmitter optical module of claim **6**,

further including a wiring substrate provided on the first carrier, the wiring substrate providing an interconnection electrically connected to the driver.

8. The transmitter optical module of claim **7**,

wherein the wiring substrate extends outwardly from an edge of the first carrier to the electrical plug.

9. The transmitter optical module of claim **6**,

wherein the TEC provides a top plate, the first carrier extending outwardly from an edge of a top plate of the TEC toward the plug.

10. The transmitter optical module of claim **6**,

wherein the multi-layered ceramics of the electrical plug includes a lowermost layer and a first ceramic layer on the lowermost layer, the electrical pad being provided on a top surface of a portion of the lowermost layer exposed from the first ceramic layer, and

wherein the first ceramic layer provides an interconnection electrically connecting an inside of the body portion to an outside thereof, the interconnection of the first ceramic layer providing an electrical pad in an end outside of the body portion.

11. The transmitter optical module of claim **10**,

wherein the first ceramic layer forms exposed areas in respective sides of the lowermost layer by exposing the top surface of the lowermost ceramic layer, and

wherein the post provided on the bottom plate of the TEC is put between the exposed areas in the respective sides of the top surface of the lowermost ceramic layer exposed by the first ceramic layer.

12. The transmitter optical module of claim **6**,

wherein the bonding wire has a top level lower than a top level of the TEC.

13. A transmitter optical module, comprising:

a semiconductor laser diode (LD) configured to emit light with a specific wavelength;

a thermo-electric-controller (TEC) configured to control a temperature of the LD, the TEC including a bottom plate and a post provided on the bottom plate thereof;

a body portion configured to enclose the LD and the TEC therein hermetically, the body portion including an electrical plug made of multi-layered ceramics including an electrical pad that supplies a current to the TEC through the post; and

a coupling portion assembled with one side of the body portion opposite to a side where the electrical plug is formed,

wherein the post and the pad are configured in side-by-side arrangement and electrically connected with a bonding wire, and

wherein the body portion provides no electrical structures in both sides connecting the side where the coupling portion is assembled to the side where the electrical plug is formed.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,331,789 B2
APPLICATION NO. : 14/075876
DATED : May 3, 2016
INVENTOR(S) : Shunsuke Sato

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Drawings

Replace Sheet 3 of 9 with attached Sheet 3 of 9 consisting of Fig. 3.

In the Claims

In Claim 6, Column 7, Line 35, replace “IBC” with --TEC--.

Signed and Sealed this
Twenty-fourth Day of January, 2017

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office

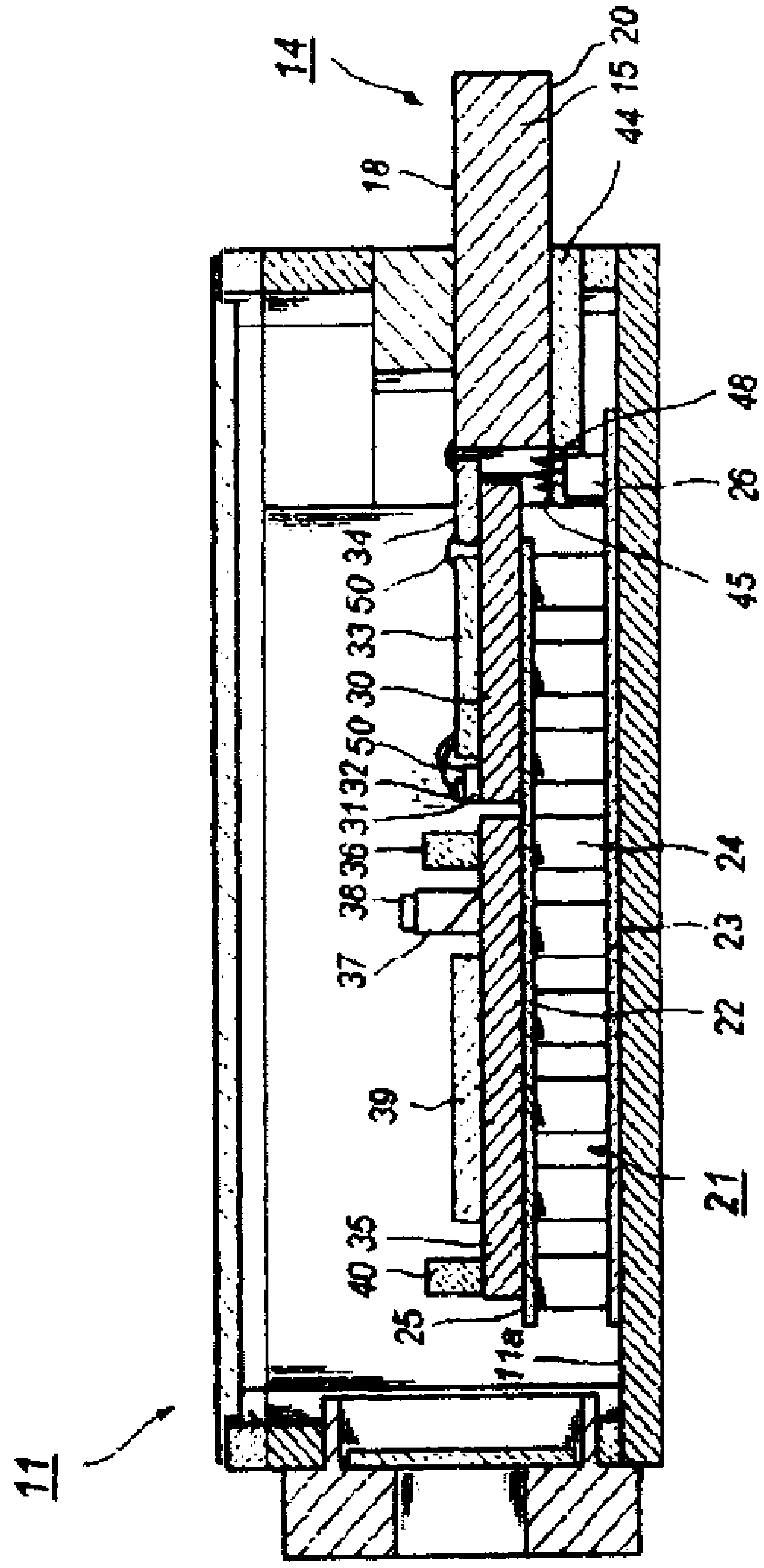
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Fig. 3